Sandia National Laboratories

Fact Sheet

LIGA Micromachining

Plastic, Metal, and Ceramic Microparts

Sandia National Laboratories has developed a complete capability to produce metal microparts using the LIGA process, and has active R&D in the areas of plastic and ceramic micro-replication.

LIGA is an acronym from the German words for Lithography, Electroplating, and Molding. It is ideally suited for making parts with depths significantly greater than nominal lateral dimensions, parts that require a particularly smooth or straight side wall, and parts from metals, metal alloys, plastics, or ceramics. In general, LIGA parts are in a size range between surface silicon micromachining and precision machining.

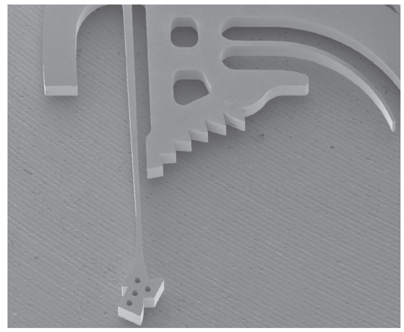
The LIGA process uses synchrotron radiation to create a pattern in an X-ray resist, usually polymethylmethacrylate (PMMA). The use of synchrotron radiation allows lateral feature sizes that are as small as a few microns in dimension, and straight and smooth vertical side walls that can be as tall as several millimeters.

Once the PMMA is exposed, it is chemically developed and used as a mold for electroforming metal or metal alloys. The electroformed LIGA mold can be used as a master mold to create plastic or ceramic microparts, or the metal parts can be the finished product.

Standard metal microparts

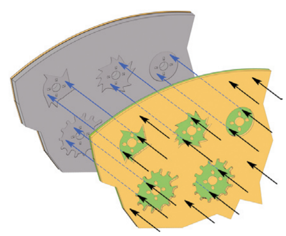
The standard Sandia process for making metal LIGA microparts includes the layout of CAD files for a three- or four-inch diameter mask. Once the mask layout is complete, a chrome mask is ordered from a commercial vendor.

This chrome mask is used to create a LIGA mask. Our typical LIGA mask is about 10 – 15 microns of gold patterned on a 100-micron silicon wafer. This mask and substrate are used to expose the X-ray resist to synchrotron radiation (step 1 in LIGA process flow figure).



50 micron Ni/Mn flexure

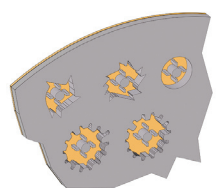
Sandia and collaborators operate dedicated beamlines at both the Stanford Synchrotron Radiation Laboratory and Advanced Light Source at Lawrence Berkeley National Laboratory.



LIGA process flow: Step 1

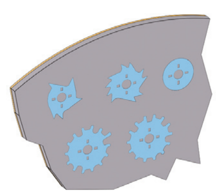
In partnership with the Honeywell FM&T Kansas City Plant, Sandia also uses a LIGA beamline at the Advanced Photon Source at Argonne National Laboratory.

After synchrotron exposure, the PMMA resist is returned to Sandia for chemical development (step 2), electroforming and planarization (step 3), and release of microparts from the resist mold (step 4). Sandia personnel conduct all process steps except the initial chrome mask fabrication.



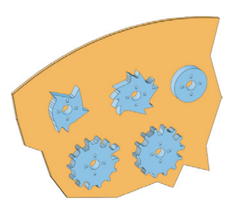
Step 2

Metals and metal alloys that have been electroformed in PMMA molds to date include nickel, copper, gold, nickel iron, nickel manganese, nickel cobalt, and dispersion-strengthened nickel.



Step 3

At the present time, our standard process allows nominal lateral feature sizes of about 10 microns, and heights up to 3 mm. The turnaround time is approximately six weeks, depending on the material choice.



Step 4

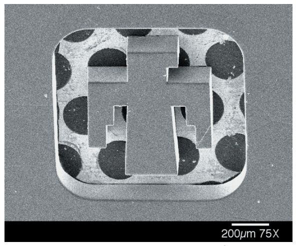
SAND2005-1601P
March 2005

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

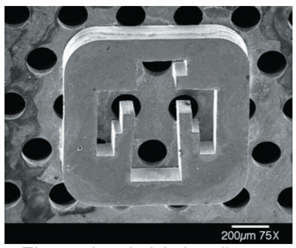
Sandia National Laboratories
AY7309

Plastic and ceramic replication

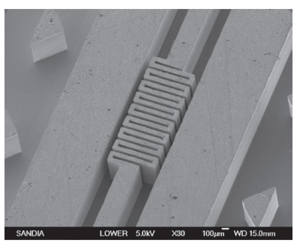
In an effort to provide a greater variety of material and design options, Sandia has an ongoing R&D effort in plastic and ceramic replication. We currently have an operational hot-embossing process which allows us to replicate LIGA or other micromolds in plastics such as PMMA, polycarbonate, polypropylene, polyolefin, and liquid crystal polymers. Our ceramic replication effort is focused on using nanoparticles in a polymeric matrix as the mold filling material. We have successfully made microparts from alumina, $MnFe_2O_4$, and stainless steel nanoparticle sintering, allowing LIGA microparts to be used for high-temperature, high-strength, or magnetic functions.



PMMA mold replicated from LIGA micro-tool



Electroplated nickel replicate with PMMA mold removed



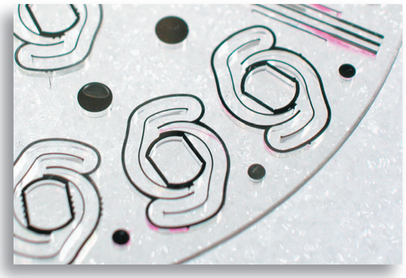
Radio frequency coplanar waveguide filter

Process research and development

Sandia has an active program in improving the LIGA processes to enable higher quality, higher yield, and lower cost. We have developed coupled models of the synchrotron exposure and development steps that allow optimum mask design, taking into account desired sidewall tolerance. This modeling effort also allows process time optimization for the exposure and development steps.

Also underway are experimental studies to improve and more fundamentally understand the PMMA adhesion to the substrate, the development process including the use of megasonic agitation, the electroforming process, and the planarization process.

In addition we have extensive dimensional and material metrology techniques for characterizing the finished product.



High-strength electro-mechanical springs and tensile test specimens

Accomplishments

Sandia's primary internal interest in LIGA is for small, rugged weapon components. We have designed and fabricated an 8 mm diameter by 3 mm thick electromagnetically driven millimotor with a torque output goal of 1.5 milliNewton meters.

Another Sandia LIGA design is a smart environmental sensing device that senses acceleration, opens up a light path, and activates a LIGA fabricated gear train. Recently we also have developed high-strength nickel-manganese LIGA components for a precision contact spring application. Another recent advance is the design and fabrication of deep copper coplanar RF waveguides for directional wireless transmission.

Sandia has conducted LIGA processing for a number of commercial entities to fabricate microparts that require LIGA features such as sidewall smoothness, material options, or high precision. In addition to the commercial partners, Sandia works closely with other national laboratories and universities on LIGA technology.

Summary

Sandia strives to continue to lead in LIGA and LIGA-like micromachining technologies. We will work with interested parties to prototype hardware, as well as in a more complete design and process development role to jump start others interested in establishing LIGA capabilities. Finally, we are establishing an intellectual property portfolio of exciting results available for licensing.

Learn more at
http://www.ca.sandia.gov/liga

For more information contact
Glenn D. Kubiak
(925) 294-3375
kubiak@sandia.gov